Identifying the Return on Investment for Army Migration to a Modular Open Systems Approach for Future and Legacy Systems

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Abstract

The National Defense Authorization Act (NDAA) of 2015, cites the modular open systems approach (MOSA) as both a business and technical strategy to reduce the cost of system development and sustainment. The Better Buying Power 3.0 directive sets the expectation that MOSA adoption will result in increased innovation and competition, leading to lower cost. With a few exceptions, policy directs developers to consider open source software first when building new capability. Even with the abundance of guidance, a lingering question remains. What is the return on investment (ROI) for building and or migrating systems to a MOSA? This research sought to answer that question.

To answer the question raised above a review of a cross-section of MOSA-related material was conducted. The material included industry analysis, system and software development best practices, government/DoD policy, and acquisition law and guidance. The research revealed an overwhelming amount of data highlighting the benefits of using MOSA both in industry and government. Industry has fully adopted MOSA and continues to innovate on ways to deliver capabilities and software services using MOSA constructs. One can see MOSA in service-oriented architecture, cloud services, modular programing, and the proliferation of open-source software.

Numerous examples of MOSA-related efficiencies were uncovered. These include streamlined development made possible by the use of modular and open-source software, reduced reliance on proprietary products by selecting open standards, ease of sustainment and upgrades made possible by modular code, well-defined interfaces using commonly agreed standards, and obeying the rules of cohesion and coupling. A number of specific project examples across government and industry attest to the value of using MOSA. While the research

did not definitively quantify the ROI for implementing MOSA, it clearly shows there is a

significant ROI for adopting MOSA.

Chapter 1 – Introduction

Background

Today's Army systems architecture is in transition from stand-alone components to a nearly seamless, systems-of-systems architecture where connectivity and software enhance the capability of the individual pieces. The tank becomes more effective when networked and receiving targeting and position data on enemy and friendly movements. Aircraft are made more effective by being networked and receiving battle damage assessments and command and control data. Command and control (C2) systems become more capable when they are networked and can share data. New technologies like virtual machines and networked services allow us to reduce the amount of hardware and software we field, therefore reducing the cost of software maintenance. Additionally, some common software capabilities that reside in every system are no longer needed in every system and are therefore duplicative. With the emergence of software technologies like service-oriented architectures (SOAs) and cloud services, key functionality can be codified in a single common software module. The module should be available to all consumers and systems that can access the service over the network. Combine the advances cited above with the emergence of systems developed using the modular open systems approach (MOSA) constructs, including open-source software—"software that can be accessed, used, modified, and shared by anyone" (Scott & Rung, 2016, p. 14)—and a whole new set of possibilities to enhance the efficiency and capability of networks (transport, platforms, and C2 systems) become achievable.

Even though the Army network is in transition, its current state is still characterized by stand-alone systems with single core functionality, system-unique data structures, and software that is tightly coupled, which makes upgrades difficult and expensive. Tightly coupled software

has high interdependence between components. A change in one component could necessitate multiple other changes. This is not because of negligence on anyone's part, but primarily due to the evolution of systems on the battlefield. Many of the current systems (Command Post of the Future, Distributed Common Ground Station–Army, Advanced Field Artillery Tactical Data System, and Tactical Airspace Integration System) were developed years ago with minimal requirements for integrating systems and sharing data. Because it's difficult to get competition for needed upgrades on the current architecture, incumbent prime contractors have significant control over future upgrades and software maintenance. Another byproduct of the current architecture is high levels of duplication across systems. For example, in Army command post there is common or duplicative functionality in many systems. A few good examples are multiple message readers, multiple applications to display the Common Operational Picture (COP) and multiple instances of authentication software. With a MOSA architecture across the command post, duplicate software and the cost of maintaining that software could be reduced. Multiple systems in the command post could use a single COP solution. With commonly agreed upon standards and open solutions, the interoperability challenge should decrease. When we begin to use common solutions with common standards, we expect cost to decrease and we can eliminate applications whose only function is to mediate between disparate applications with different standards. Finally, stovepipe systems with tightly coupled code make it very difficult if not impossible to attract new vendors to compete for contracts to update systems. Because this software is likely proprietary, it is not practical from both a legal and a technical perspective for new vendors to bid on upgrades. This situation stifles new innovation on the system and limits the source of new ideas on how to improve the system.

Before we go further we need to provide some basic definitions to set the proper context and provide clarity for the reader. The National Defense Authorization Act (NDAA) for 2015 defines the open systems approach as it relates to information technology systems as

…an integrated business and technology strategy that (A) employs a modular design and uses widely supported and consensus-based standards for key interfaces; (B) is subjected to successful validation and verification tests to ensure key interfaces comply with widely supported and consensus-based standards; and (C) uses a system architecture that allows components to be added, modified, replaced, removed, or supported by different vendors throughout the lifecycle of the system to afford opportunities for enhanced competition and innovation… (sections 3426–3427)

One of the upfront challenges of doing the research was the inconsistency across the Department of Defense (DoD) on what the "A" in the MOSA acronym stands for. In some documents it represents "architecture" and in other places the "a" is for "approach". The MOSA definition is fairly consistent with one exception. The Navy explicitly includes open source in their interpretation and they call out software reuse as a MOSA objective. According to the open systems architecture contract guidebook (DoD, 2013), modular dsign is "a design (organization) where functionality is partitioned into discrete, cohesive, and self-contained units with well defined, open and published interfaces that permit substitution of such units with similar components or products from alternate sources with minimum impact on existing units" (p. 138).

As far back as the 1970s, colleges and universities have been teaching computer scientists and software engineers that software should be built in discrete modules that are cohesive in functionality within modules but loosely coupled between modules to ensure that changing one module does not drive a change in any connected module (Yourdon and Constantine, 1979). The

MOSA approach lowers the bar for vendors seeking to compete for software upgrade contracts by promoting open standards and removing the challenge of developing code that must interface with propriety standards and code. According to the NDAA for 2015, implementing MOSA will yield significant cost savings and greater interoperability. The NDAA for 2015 directs the Services to report on their efforts to transition major defense acquisition programs (MDAPs) and major automated information systems (MAIS) to MOSA, highlighting any issues and how those issues could be addressed. According to Gavin (2009), having the right strategy for how we develop systems and software is becoming more important for multiple reasons. They include the high cost of software development and sustainment, the steep rise in the amount of software in defense systems, and our critical dependency on software for all aspects of society.

Software in DoD systems has increased by more than an order of magnitude every decade (Scherlis, 2012). The amount of software in weapon systems is increasing at a staggering rate. According to Lockheed Martin (2015), each F-35 Raptor will have close to eight million lines of code, more than any aircraft built previously. There are major challenges in software development today. One is the cost of software and its sustainment over the systems life cycle. By most estimates, the largest slice of a systems life-cycle cost is operations and sustainment cost (Haines, 2001). Another related challenge is the work and cost associated with making required software updates and the associated integration. This challenge is exacerbated by the high rate of hacking incidents and the rapid introduction of malicious code, which threaten the security and performance of systems and networks. Recent red team assessment of operational exercises (network integration events) reveals significant vulnerabilities in our systems and software. Cyberattacks are becoming more numerus and more effective according the Bennett (2016). To survive in the current cyber environment, developers must be able to incorporate

upgrades rapidly. Government systems across many departments, including defense, energy, the Environmental Protection Agency, and homeland security must enable rapid integration of updates. Systems that can be easily updated based on changing requirements and threats to those systems are needed to maintain performance and system security.

The DoD has been pushing the importance of MOSA in law, policy, and acquisition contract guidance since at least 2004. DoD industry partners generally agree with the strategy and are applying MOSA to many programs, both defense related and commercial. Our lawmakers have integrated MOSA mandates in law. However, we are still moving slowly in transitioning to MOSA for current and future systems, and we don't have adequate data that quantifies the cost savings to be achieved.

Problem Statement

The expected benefits of transitioning to a MOSA for acquisition programs include reduced cost, increased competition and innovation, and ease of integration and sustainment. A big challenge will be to transition existing systems to MOSA; this will be costly and will occur over many years. It will require changes in existing contracts and a shift in how we approach intellectual property. However, little data exist that quantifies the possible return on investment (ROI) for transitioning programs to MOSA. Significant concerns about the status of MOSA implementation were raised by survey results collected by the Army-led, joint Better Buying Power 3, MOSA study team, which primarily consisted of general officers and Senior Executive Service-level acquisition leaders. Key concerns included the following according to S. Blanchett (personal communication, March 15, 2016):

1. The PM's staff lack the experience required to implement MOSA.

2. Clear guidance on MOSA compliance is lacking on all levels.

3. Incumbent contractors have little incentive to cooperate with MOSA goals.

4. Associated intellectual property guidance lacks clarity and consistency.

While it may appear intuitive that migrating to MOSA will reduce the cost of developing and sustaining systems, there is little quantitative data on the expected savings. This research attempted to identify and quantify the ROI for transitioning programs to MOSA.

Purpose of This Study

The results of this study should inform acquisition leaders and practitioners about the ROI for migrating to MOSA. In order to weigh the promise of MOSA and the current state of MOSA migration, this study assessed a significant body of data on modular design and open systems approaches and sought supporting and contradictory information on the value of MOSA. . It focused on current technologies and practices in the area of MOSAand highlights successes in MOSA compliance and issues affecting adoption and migration to MOSA. Concrete examples are given of where a positive ROI has been realized from taking on MOSA. The study sought to explore the following questions.

1. What is the expected ROI for MOSA migration?

2. Will Army systems under a MOSA construct ease the challenge of upgrading and integrating systems and platforms?

3. Should MOSA be applied to systems/platforms in sustainment?

Significance of This Research

This research is significant because of its potential to shed light on how we can improve acquire, sustain, and update our military systems. The research results help to validate the value proposition for MOSA, which consists of increased competition, simplified upgrades through modular design, common open standards, delayed obsolescence, and reduced sustainment cost

through open approaches and increased innovation. The DoD must improve its ability to develop and maintain systems and related software. It is critical to our ability to deliver capability to warfighters. Many challenges are associated with improving system performance and security while reducing delivery time and cost. We must address all the challenges in a time of shrinking defense spending coupled with the emergence of adversaries' peer or near-peer technology and systems. Numerous government and industry leaders believe using open systems approaches coupled with adopting modular designs will address many of the problems identified above. Both Secretary of Defense Carter and the defense acquisition executive, Mr. Kendall, urged the adoption of MOSA across DoD. The Defense Department's Better Buying Power initiatives continuously urge the use of modular design and open systems approaches to address the stated objectives and shortcomings. According to Fitzgerald, Levine and Parziale (2016), America's ability to regain/maintain our technological edge over our adversaries is linked to whether we embrace and prioritize open systems. This study addresses some of the foregoing concerns and sheds new light on the topic.

Overview of the Research Methodology

The hypothesis for this paper is that applying MOSA to Army systems will reduce the cost of system development and sustainment. We know there will be some upfront cost associated with developing new systems and/or transitioning existing systems to MOSA, yet the expectation is that there will be a positive ROI. A mixed methodology was used for researching this topic, including evidence-based research and case study research, both supported by a literature review. This evidence derives from an examination of MOSA-related data, studies, journals, papers, successful and unsuccessful initiatives, and associated technology. The research also includes previously conducted surveys on the topic of MOSA.

Limitations

Determining the ROI for adoption of MOSA would require a clear determination of the cost to adopt MOSA. A commonly accepted cost for adopting MOSA in DoD does not exist. Therefore, for the purpose of this research, ROI equals cost savings plus cost avoidance in development and sustainment attributed to the adoption of MOSA. The initial review of literature and evidence on MOSA found little quantitative data on the cost savings associated with modular design and open systems approaches. Many of the sources reviewed include statements about the value proposition for open systems approaches. Part of the value proposition is that open software can be obtained at reduced cost. There is also evidence that increased participation in open forums will yield software code and technologies that were not developed at government expense but provide great value because participation allows participants to shape solutions to meet their needs.

The second limitation is that surveys and interviews were not developed or conducted as part of this research. This limited the ability to include specific cost data from the MOSA efforts of program managers and industry developers.

Chapter 2 – Literature Review

The literature review focused on four areas:. (1) MOSA-related technologies and related processes; (2) past, ongoing, and planned MOSA efforts across the government and industry; (3) studies, papers, journals, policy, and guidance on MOSA; and (4) documents with quantitative data that contain specific accounts of savings reaped from MOSA implementation. Multiple sources and source types were used for each category, including legal documents; government reports, studies, and survey results; books; and online material (blogs, journals, and other web content).

MOSA technologies and related processes. In the area of technology, several key products are included. Fogel (2009) provided a brief but thorough history on open source software (OSS) efforts, including both successes and failures. He discussed the key players and motivations in open source projects, ranging from the project originator who has a need or interest in a certain product, to the partners who have a shared interest in the product and are willing to help develop the code. According to Fogel, an early example of an open source project (and one of the best) was the collaboration to develop the hardware independent, UNIX operating system. The academic community joined forces from geographically dispersed locations to lead that development. Perhaps the most popular and far-reaching example of an open source project is the Internet/World Wide Web. Fogel also gave a step-by-step guide on how to initiate and manage a free software project, addressing key details from the technical infrastructure, to requirements, to open source licensing options. In chapter one the author tackled and clarified the word "free" in the context of free software. According to Fogel, "free" in the context of free software refers to the freedom to do what you want with the code, including sharing, changing, and adding features. The example Fogel used in the book is the battle between

Microsoft and Netscape in the 1990s to capture the browser market. Both companies gave away their browsers free of charge, but users were not free to make changes to the code. Hence, free in this example did not mean free to share, upgrade, or change the code in any way. In essence the products were free of charge yet proprietary. From a government perspective, under the MOSA construct we want products that are free from both perspectives, free of charge and free to manipulate. One of several important aspects of Fogel's book is his introduction and analysis of intellectual property and its relationship to competition.

Another source used was a technical paper from the Center for a New American Society. The authors (Fitzgerald et al., 2016) make a compelling case that beyond reduced cost, interoperability, and innovation there are additional and equally important benefits of a MOSA. They see MOSA as an essential component of the acquisition ecosystem the country must have to produce the kind of software and system capabilities needed to keep pace with our adversaries. Fitzgerald et al. (2016) highlight the gap between industry's heavy reliance on MOSA as a catalyst for rapid development of cutting-edge software and the DoD, which they say does not prioritize software development at a high enough level. They see MOSA as a critical component of our ability to win the technology race. Fitzgerald et al. say that implementing MOSA creates a software platform that will accelerate innovation of software/system capabilities. In summary, the research revealed that open systems is more about adopting a new technical methodology for acquiring capability that reduces cost, eases the interoperability challenge, and enables greater innovation and competition.

Past, ongoing and planned MOSA efforts across the government and industry. To identify and create a baseline for the status of MOSA, a number of MOSA initiatives were investigated, including but not limited to the following products. As mentioned in the previous

section, one of the most notable past examples of an open source initiative was the development

of protocols and standards that power the Internet: Open Systems Interconnect (OSI) and

Transmission Control Protocol/Internet Protocol (TCP/IP). According to Kelty (2009), "the

success of TCP/IP protocols forced multiple competing networking schemes into a single

standard—and a singular entity, the internet…" (pp. 38-39). The early efforts like TCP/IP and

OSI helped shape the concepts and identify the goodness of free software and open source. The

Navy, Army, and industry initiative—Future Airborne Capability Environment (FACE)—is an

industry-government consortium that is developing an open computing environment and open

software standard for fixed and rotary wing aircraft. FACE is a trademark of The Open Group,

which is a global consortium that enables the achievement of business objectives through IT

standards (Stevens, Howington, Boyett, & Avery, 2016). If properly implemented, FACE

promises to deliver modular open components that can be ported from one platform to another

with minimal integration challenges.

The Army's Common Operating Environment (COE) is yet another effort that embraces

MOSA. The Army COE includes FACE and Vehicle Integration for C4ISR/EW Interoperability

(VICTORY) as part of an overarching initiative to speed the delivery of capability to the soldier.

These initiatives also reduce system development cost and time required to react to changing

warfighter needs. The COE effort began with an Execution Order from the Army Chief of Staff

directing COE implementation. The order was subsequently followed by an enterprise

architecture developed by the Army chief information officer and an Information Systems

Capability Development Document developed by Headquarters TRADOC. A core component of

the COE strategy is to transition legacy systems to a MOSA. The strategy also encourages

operational functionality to be encapsulated in widgets and/or applications integrated on a

common software platform. This approach emulates industry MOSA constructs such as the
Google Android software platforms, which form part of the ecosystem for the millions of
functional apps and widgets available for use by smartphones and tablets. Figure 1 is the COE
Technical Reference Model, showing the layers of a modular architecture from transport, to
common services used by all, to user-facing functional widgets and apps used by the soldier.
These apps and widgets aid the soldier in numerous ways, including route planning, viewing the
common operational picture, and C2 functions. It's important to highlight here that once the
industry platforms were developed, unprecedented innovation on the apps and widgets occurred,
generating millions of modular applications and widgets representing a wide range of
functionality. It's safe to say that no one could have imagined the amount and types of widgets
that were developed for Android and Apple.
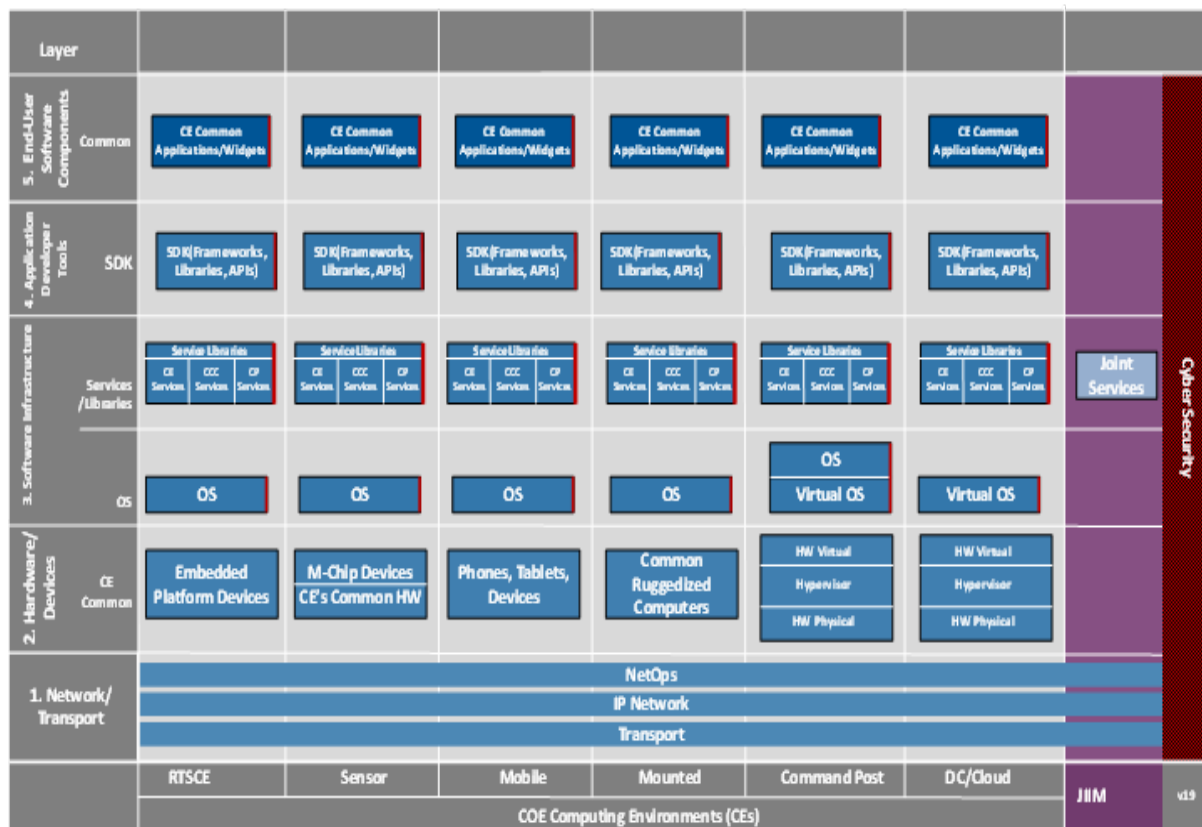
Figure 1 – The Army Common Operating Environment Technical Reference Model

The Army VICTORY initiative is an open specification focused primarily on sharing information between components on ground platforms. The VICTORY architecture is based on common interface standards implemented across a common vehicle bus. Once these standards are implemented, platform owners will have a plug-and-play-like experience when integrating IT and communications electronic components on the platform. VICTORY will also take into account the size, weight, and power constraints of the platform. In summary, research revealed multiple examples of successful modular open architecture efforts and some failures. Many industry open-source products are thriving. The FACE initiative appears to be on the edge of delivering on the promise of an operating environment for aircraft that can produce reusable open code for use in multiple platforms.

There are numerous open-source initiatives in industry. One popular initiative is web servers. These open source products dominate the web server landscape, and they make up the software responsible for the distribution of content on the World Wide Web. According to Muilwijk (2016), Apache and NGINX web servers together power over 80 percent of all web sites. The significance here is huge, project managers with a requirement to serve content over the web can forgo the challenge and the expense of developing a web server. The program manager who needs a web server can choose to use one of the open source products.

Studies, papers, journals, policy, and guidance on MOSA. In this area there are many documents: The NDAA of 2015, section 801; the Better Buying Power 3.0 directive from the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]); and the open systems architecture contract guidebook all provide direction to the Services on moving forward with MOSA. According to the NDAA of 2015, the Services should be pursuing MOSA

for MDAPs and MAIS to reduce cost. In Better Buying Power 2.0, systems developers were instructed to use open systems for the acquisition of new systems. The Better Buying Power 3.0 directive instructs the acquisition community to use MOSA to stimulate innovation (Kendal, 2015). According to policy issued by the Director for Defense Systems (Lamartin, 2004), acquisition programs are to address MOSA early in their program acquisition planning as a means to develop the future capability needed for our soldiers, sailors, and airman. There is no shortage of guidance and directives urging the use of MOSA.

Documents containing dollar amounts or examples of specific quantities of funds saved by implementing MOSA. Information in this category is sparse. A report, endorsed by the Committee on Aging Avionics in Military Aircraft, captured the results of a detailed analysis on how the Services might address the problem of aging avionics in aircraft (Air Force Science and Technology Board, 2001). According to the report the cost associated with replacing avionics components once they became obsolete was very high. One of the recommendations in the report was to adopt MOSA in the development and maintenance of aircraft, specifically the avionics. The report includes a finding that the widespread application of MOSA would make the management of the ageing avionics problem more affordable.

The Navy distinguishes itself by embracing OSS under their open architecture construct. Gavin (2009) provides a long history of the Navy's engagement with open architecture. His presentation highlights the Navy's open architecture construct and core principles, which include moduler design and life-cycle affordability. According to Gavin, an open source strategy is essential for the 21st century and is a means to achieve more reliable systems and to increase innovation. The Navy specifically identifies greater software reuse as an objective. The other Services and organizations seem to limit their definition of open approaches to open

architectures and open standards. Gavin's presentation traces the history of open architecture from 2004 to 2009. Key milestones along the timeline include the issuance of operational architecture and requirements policy. According to Gavin, significant accomplishments tied to open architecture implemention include component reuse across the Marine Air Ground Task Force (MAGTAF); reduced cost, per boat, per year of $2.9 million for the submarine warfare tactical system; and reduction of shipboard networks to one, after implementation by Consolidated Afloat Networks and Enterprise Services (CANES), resulting in a $4 million saving per ship. Table 1 shows the accomplishments across multiple Navy programs.

Table 1 – Progress Across the Navy Enterprise

Open Source Approach Across the Navy Enterprise			
Navy-Marine Element/System	**Action**	**ROI**	**Impact**
MAGTAF C2	Reusing components across systems reduces cost		Reduced cost
Mobile User Objective System	Use of commercial standards for waveform		85% reused or modified software
P-8A	MOSA as technical criteria		68% reuse of mission software
Littoral Combat Ship Mission Modules	Uses well-defined interfaces and commercial standards		
Submarine Warfare Federated Tactical System		Reduced cost per boat by $2.9 million per year	
Common Processing Unit	Use of commercial Hardware/Software		
CANES	Reduced 4 shipboard networks to 1	Saved $4 million per ship (estimated)	

Chapter 3 – Research Methodology

Research Hypothesis

For this research project, the hypothesis is that applying MOSA to Army systems will reduce the cost of system development and sustainment.

The alternative hypothesis is that applying MOSA to Army systems will ease integration and upgrade challenges. There is general acceptance that MOSA will reduce the cost of system development and sustainment. There are several reasons for this effect. Over time, buyers have learned that prices are lower when there is competition in the marketplace. This rule applies to the acquisition of systems and software. The use of OSS and especially open standards allows the government to reap the benefits at the expense of others. The cost of developing the open products were borne by others who developed the products. Using modular design and open standards should drive down the cost of maintenance and updates and any attendant integration cost.

Given the known cost drivers identified above the research sought to uncover data and quantifiable information at a lower level of granularity than what is already available.

Research Design

In order to address the hypothesis and related questions, the research followed the following methods.

1. Case Study Research. As a means to investigate the hypothesis, research assessed many software development programs and initiatives. First the research sought to determine whether some aspect of MOSA is being used by the program or initiative. The three key MOSA aspects are modular design, agreed standards, and the use of open source products. If any one of the three aspect exists, the case was assessed.

2. Causal Correlation Research. The research sought to discover the relationship between MOSA and cost. For example, if there is a relationship between competition and cost, the research would expose that relationship and uncover instances where there has been an impact and the level of the impact. The aim is to identify specific examples in the literature that highlight concrete cost savings realized after transitioning to MOSA.

3. Evidence-based Research. Evidence-based research was used widely throughout the project to identify and analyze any evidence pertinent to proving or disproving the hypothesis.

Bias and Error

Close attention was paid to ensure that bias was not introduced in the research. Because so much attention is being paid to MOSA implementation at the highest levels within the DoD, some may be tempted to overstate the success of their program with regard to supporting or disproving the value of MOSA. Additionally, a significant amount of data on MOSA represent the views of industry, academics, and practitioners. All data was evaluated to eliminate inaccuracies from any source. Where feasible, peer reviews were used to further attempt to reduce bias and errors.

To ensure the validity of data and associated findings and recommendations, information was cross-referenced by using multiple sources when possible. Inquiries were made to verify information. According to Calabrese (2006) "validity refers to the accuracy or usefulness of a measurement" (p. 58). Another approach used to bolster research validity was to include in the review any data supporting or countering the research hypothesis. Finally, peer reviews of the paper served as an additional means to ensure accuracy and validity of data.

Chapter 4 – Findings

The focus for this research was to identify the ROI for building new systems and migrating existing programs to MOSA. The research uncovered lots of data on MOSA, its definition, components, expected benefits, and insights into the level of adoption across industry and the DoD. One finding that should be mentioned up front is that while OSS was not widely mentioned in most of the data reviewed (with the exception of Navy documentation), OSS should be included or at least considered in any discussion of MOSA. In accordance with the DoD's open systems architecture contract guidebook, "OSA principles are also supportive of and consistent with using Open Source Software (OSS) in systems….use of OSS does not, by itself, constitute compliance with OSA" (DoD, 2013, p. xi). From this point forward in the research, OSS will be addressed as an essential component of MOSA. In addition to the primary question related to the ROI from MOSA, the analysis addresses the following related questions:

1. What is the expected ROI for MOSA migration?

2. Will Army systems under a MOSA construct ease the challenge of upgrading and integrating systems and platforms?

3. Should MOSA be applied to systems/platforms in sustainment?

The Effect We Want from a MOSA on Our Systems

From a high-level perspective, MOSA has two main components: a modular architecture and an open systems approach. Taken separately, each one can have a significant impact on reducing the development and sustainment cost of systems; when implemented together they can become a game changer in terms of ROI, as well as for speed of product delivery, ease of integration, and increased innovation. According to the Air Force Science and Technology Board (2001, p 32) a modular system has the following attributes:

- The system is designed to maintain external hardware/software interface capability of a module independent of changes made internal to module

- Both hardware and software (physical and functional/logical) aspects of architectural interfaces are included in the system.

- The systems can be scaled in capability by incrementally adding or deleting modules of functionality

- The systems can be maintained or upgraded by selective replacement of elements without impacting the other elements

- The systems can reuse existing elements and provide reusable elements to the other systems

By contrast open systems have the following attributes:

- All the attributes of a modular system are also included in an open system

- The system can be integrated from elements supplied from multiple sources

- Choice/application of standards represent a design decision that follows open system partitioning and functional interface definition

These attributes taken together provide a description of how we want future system to be developed.

Analysis

Research results show a high probability for realizing a positive ROI for implementing MOSA. After reviewing data and analysis from both industry and the DoD, the findings reveal there is and would be a high return on investment across both DoD and commercial industry. Both industry and the DoD have experienced benefits from MOSA, but the industry experience has differed from the DoD experience. Industry moved relatively quickly on many aspects of

MOSA and continues to innovate on the MOSA technologies. Industry has pushed forward with OSS, service oriented architectures, and cloud services to name a few. In some cases the DoD has adopted some of these technologies and in some cases it is playing catch-up from a distance. The DoD is using MOSA, specifically a service oriented architecture, to incrementally replace legacy C2 systems (Kendall, 2017).

Industry adopts MOSA. Industry has clearly adopted and embraced MOSA in a significant way, and they have seen the biggest ROI from MOSA. We simply have to look at the Android market to see how the application of MOSA (e.g., open standards, modular architecture, OSS) has led Android to be the leader in the mobile device market. Android is built on the Linux operating system, which is OSS. Apple and its modular IOS platform has also had tremendous success with MOSA, even though it's not fully MOSA because of its proprietary platform. According to The Statistics Portal (2017), Android users had 2,800,000 apps and Apple users had 200,000 apps to select from. The diversity of app providers and the total number of apps indicate a high level of competition and innovation in the space. Competition and innovation are two key DoD objectives for using MOSA, according to the USD(AT&L)'s Better Buying Power initiatives.

According to Gavin (2009), the use of OSS in the private sector is on the rise. Both DoD and the private sector use OSS in critical applications. Two examples often mentioned include Android and Apache open software products. The Army chose the Android operating system for its Net warrior system partly because it is derived from Linux, open software. There is no up-front charge for using Android; however, some device manufacturers must pay fees to get a license to use some of the related software applications. The Apache web server may be the world's most used web server, and it is also used widely across the DoD. Both industry and the

DoD rely heavily on web apps and services. Apache is OSS, and it is free when acquired from the Apache Software Foundation. According to Fitzgerald et al. (2016) the Apache Foundation has software on almost half the web servers worldwide. Apache has a liberal use license that allows users to modify/extend the software as required.

The value of OSS. To quantify the ROI for migrating systems and programs to a MOSA construct, first you must have a way to determine the value of OSS. Second, you must determine what it would cost your program if you did not have access to OSS and had to develop the code on your own. For example, the popular Linux-based operating system Fedora, which is OSS, would cost an estimated $11.5 billion to build according to Vaughan-Nichols (2009). The estimate is based on analysis done by Black Duck Software, an open source legal management firm using the popular cost-estimating tool Constructive Cost Model. The firm estimates "there is [*sic*] over 200,000 open source projects representing 4.9 billion lines of code," and that it would cost $387 billion to reproduce (Vaughan-Nichols, p. 5)

The challenge of developing software intensive systems in the OSS era is getting simpler. Instead of developing and integrating disparate and often proprietary components as in the past, there is a new model. In the new model the lead engineer can just select from a list of OSS products and integrate them. He can select an operating system, a database management system, a web server, and an application server, all well documented, open source, and many free of charge.

Is open source software secure? Numerous questions have been raised concerning the security of OSS, but many of the myths about the OSS used in a national security context have been debunked. According to Fitzgerald et al. (2016), using open source code does not mean you must share the changes you make to the code publicly and, because OSS code is viewable, does

not mean the code, once deployed, can be modified by a third party. According to Winnergren (2009), OSS is consistent with commercial software and should be given preference over custom software when it is found to satisfy requirements. A custom software solution should be used only when an OSS solution can't be found. Custom software should be developed and published as OSS so it can be used by others with a common need (Scott & Rung, 2016). Finally, the level of scrutiny that happens under open development works to minimize the possibility of a hidden bug getting into the code.

Industry has embraced MOSA/OSS. Without a doubt these technologies definitely offer a positive ROI from multiple perspectives. The technologies have reshaped how industry delivers IT services to the market. Industry quickly realized the efficiencies and cost savings to be had by using MOSA. They offer agility in how they deliver capability, they foster innovation and competition, and they reduce the burden of software sustainment. According to Fitzgerald et al. (2016), "without open source, Facebook, Google, Amazon and nearly every other modern technology company would not exist" (p. 5).

MOSA in DoD

The adoption of MOSA within the DoD lags behind industry; this may explain the lack of program-specific data on the ROI for MOSA adoption. Guidance on implementing MOSA across the DoD is pervasive. The guidance can be found everywhere. The NDAA of 2015 directs MOSA implementation specifically at the program level and the enterprise level. Services were required to report on their efforts to implement MOSA. Repeated guidance from the USD(AT&L) to implement MOSA appears in all three iterations of Better Buying Power. The Department of Defense Instruction 5000.2 (DoD, 2017) directs program managers to incorporate MOSA efforts in their program acquisition strategy. The department has also issued guidance on

how to structure contracts, with specific language to support the move to MOSA (DoD, 2013).

Acquisition guidance on MOSA continues to flow out and appears to have a rising urgency and

mandate to use MOSA in acquisition programs.

The Army COE. The Army Chief of Staff issued an execution order in 2010 directing

the Army to begin development of an Army COE to reduce the cost of system development and

sustainment, to reduce the time required to deliver capability to the force, and to bring agility to

our ability to react to the changing needs of the warfighter. The COE is a set of standards and

computing technologies that enable the rapid development of applications that can be integrated

across multiple computing environments. The COE embodies the MOSA construct and is being

applied across handheld, ground, air, mobile and command post platforms. The Army is

converging on a common platform for handheld devices in the mission command environment.

Instead of developing and maintaining a different mobile device for each application, a single

device will have the applications needed for many functions, such as fires, medical, and language

translation. The same construct is being applied to the command post, where tens of systems will

be converged on a common software platform so the soldier in the command post can use a

single system with a common graphical user interface to do multiple functions (e.g., intel, fires,

route planning). After six years, progress is being made on many fronts, and we are reducing the

number of separate systems over time. Program managers who provide systems for the command

post have begun to develop widgets that will ultimately replace the stand-alone legacy systems.

Well over 50 widgets have been developed. These widgets rely on a common software platform,

and because of the modular open approach, the expectation is that many vendors can compete for

widget development and innovate new solutions. OSS makes up part of the common software

platform. As a result the Army will reduce sustainment cost and the amount of software it maintains and speed up the time required to update or change an existing capability or app.

Modular design, open architecture, and OSS all act to delay and reduce obsolescence and ultimately to reduce the cost of providing capability. According to the Air Force Science and Technology Board (2001), in fiscal year 1999 the Air Force was spending $1 billion on sustaining aircraft avionics and needed between $250 and $275 million additional per year to address the problem of aging avionics in new and legacy aircraft. According to Air Force projections, those costs were expected to rise over the next 5 years by 50 percent. Combating obsolescence is a critical challenge for DoD systems. Unchecked obsolescence of DoD systems works to increase the cost of systems and decrease the systems' effective life. According to the Air Force Science and Technology Board (2001), "military equipment ages in two basic ways: obsolescence in hardware or software that renders the equipment insupportable; and inadequate performance that renders the equipment unable to fulfill its mission" (p.10). By developing capability in loosely coupled software modules and using open standards, obsolete capability can be easily updated with the minimum amount of software to get the job done while keeping the parts that still work. Integrating the modules with open standards eases the integration of the new software and promotes competition among firms who want to build the updated software.

MOSA applied across the Navy Enterprise. The Navy has had many successes with the application of MOSA across a number of programs. One such effort is the CANES initiative, which embodies the MOSA construct and is changing Navy shipboard C2. "CANES is a shipboard tactical network that provides ships with services including improved information assurance, firewall and intrusion detection as well as greater flexibility enabling for an adoptable IT platform to meet requirements for current operating systems and easy upgrades when they

become available" (Pomerleau, 2016, p. 2). According to Gavin (2009), CANES reduced shipboard networks to one and is projected to save $4 million per ship in a notional carrier configuration.

MOSA and Intellectual Property (IP)/Data Rights

As the department seeks to accelerate migration to MOSA where it makes sense, close attention should be paid to how MOSA will change IP and data rights practices. As the number of vendors competing for contracts to update and sustain MOSA-compliant systems increases, an increase in the number of IP and data rights problems is expected. The expectation is that we will see the new MOSA environment unleash competition and innovation. Once vendors understand the new open environment and the relative ease of developing software, the number of software apps being offered to the government will increase. This will add complexity to how we develop and manage contracts. We are likely to transition from a few monolithic applications to a large number integrated in a common foundation. The developers of these new apps will likely have IP and data rights issues that must be addressed.

Summary

The research uncovered a significant amount of data that highlights the benefits of using a MOSA for new and legacy systems. The Air Force-sponsored analysis shows a MOSA approach that offers tremendous benefits in reducing the sustainment cost for aircraft and for holding back obsolescence for these critical, long life-cycle systems. Several Navy examples were cited that show cost savings as well as increased efficiency in reducing redundant hardware and software. The CANES initiative is already producing cost savings and a positive ROI. The Navy also makes the connection between MOSA and improved software reuse. The Army has

several MOSA initiatives (VICTORY, Hardware/Software convergence, FACE, and COE) that are expected to have a substantial positive ROI once they reach maturity.

Industry has fully leveraged MOSA in many ways. Technologies like the service-oriented architecture, cloud services, and the mobile device explosion are all anchored in MOSA, and they have made billions of dollars for commercial industry. According to the research results, some industry leaders owe their existence to MOSA. Industry has outpaced the DoD in the adoption of MOSA, mostly for good reason. As we seek to maintain or regain our technological edge in defense, MOSA will play a significant part in building, protecting and sustaining our systems.

Chapter 5 – Interpretation

The collection and analysis of MOSA-related data focused on determining whether there is a positive ROI for adopting MOSA. Interpretation and analysis of the data showed numerous benefits of using MOSA. The benefits include reduced cost of development and sustainment, simplified integration of new capability, and reduced time to develop or update capability. One is not likely to see all these benefits on each MOSA-related initiative; some will have only one or two. The research strongly supports the potential of a positive ROI for using MOSA.

Conclusion

Based on the research and analysis completed there is and will continue to be a positive ROI for developing new, and migrating existing, programs/systems to a MOSA. While it's hard to quantify the ROI (savings, cost avoidance), it is clear that MOSA is the right strategy in many cases and should always be considered. Based on projected savings in the area of avionics, convergence of hardware and software to a MOSA construct is expected to yield an ROI in the hundreds of millions of dollars. MOSA represents change, and change disrupts the current state. We must find a way to address the many sources of resistance to MOSA. The sources of resistance are rooted in technical differences, current developers' fear of lost revenue, and resistance to change.

The research proves the stated hypothesis that "applying MOSA to Army systems will reduce the cost of systems development and sustainment." However, the research results did not fully quantify the ROI for MOSA implementation.

Recommendations

1. Resist broad MOSA mandates on systems without a business case analysis to ensure the approach is effective for the program or system being considered. MOSA should not be

applied as a silver bullet to all programs, especially legacy systems. There will be instances when

applying MOSA will not make sense. Examples include when a program is scheduled for end of

life or when the program architecture will not benefit from MOSA migration.

2. Identify ways to incentivize program managers to implement MOSA. Migrating

systems to MOSA will likely constitute a significant change for the program and could drive

adjustments to the program baseline and interrupt exiting contracts and contractors. Because

program managers will likely face pushback managing the change, giving them an incentive may

help the process go more smoothly.

3. Engage with current systems maintainers to address their fear of loss of income. As

mentioned previously the incumbent contractor will likely resist the switch to MOSA. At best it

will result in competition for the contractor. The prime contractor on the program and industry

overall should understand that they can still thrive in a MOSA environment. It's up to the

government to help them see success in a MOSA environment.

4. Increase training on ways to implement MOSA. It's not okay to assume that program

managers and their staff understand how to implement MOSA. Additional training should be

made available upon request.

5. Fully embrace OSS as a component of MOSA. It has been identified as a key

component of modular open systems approaches. Government policy directs serious

consideration of OSS before developing new software products. Using OSS can reduce

development and sustainment cost. A potential added bonus of using OSS is it can reduce your

development time by using software that has already been developed and tested.

6. Promote the FACE approach as a "best practice" for MOSA, with DoD and industry

partnerships. The FACE consortium includes industry and government working to define the

specifications, standards, and compliance criterion for FACE. Industry and government jointly developing the products and processes under an agreed governance structure is an ideal approach to building products and trust that benefit all.

7. Continue to develop and refine metrics for MOSA implementation. While the open source architecture task force and the Navy have developed MOSA compliance products, there is still a need for additional metrics to help program managers assess their progress.

8. DoD must engage more in standards organizations and OSS forums. To ensure the right standards are developed and chosen will require engagement by DoD in the forums that are often led by industry. Likewise, engaging in OSS forums give the government a chance to shape the final product in a way that best serves the government.

9. Future research in the area should focus of automated tools to evaluate legacy code for the existence of modular code and openness.

Limitations of the Study

As currently defined, MOSA is a broad term and touches many aspects of systems and software. Because of the complexity of MOSA, it's probable that more program managers are implementing some aspects of MOSA but are not publicizing their efforts; consequently, this research probably missed some MOSA-related work being done across the DoD. There was inadequate data to determine the cost of DoD participation in standards-setting organizations and open software forums. This must be determined to fully quantify the MOSA ROI. As stated earlier, the research clearly supports the hypothesis, but the data collected and associated analysis does not quantify the MOSA ROI.

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Glossary of Acronyms and Terms

C2...................command and control

CANES ....Consolidated Afloat Networks and Enterprise Services

COE................Common Operating Environment

COP...............Common Operational Picture

DoD................Department of Defense

FACE ....Future Airborne Capability Environment

IP ....intellectual property

MAGTAF.......Marine Air Ground Task Force

MAIS..............major automated information system

MDAP............major defense acquisition program

MOSA............modular open system approach

NDAA............National Defense Authorization Act

OSI.................Open Systems Interconnect

OSS ....open source software

ROI.................return on investment

SOA................service oriented architecture

TCP/IP............Transmission Control Protocol/Internet Protocol

VICTORY......Vehicle Integration for C4ISR Interoperability

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